The vegetation map of France going numerical: a new harmonised national geographical database

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Abbreviations
BDGveg_FR = *Base de Données Géographique de la VÉGétation de la France* (geographical database of the vegetation of France)
CNRS = *Centre National de la Recherche Scientifique* (French national centre for scientific research)
VMU = Vegetation Mapping Units

Abstract
In this paper we present the digitalisation of the map of the vegetation of France edited in 64 sheets by the CNRS between 1947 and 1991. The geographical covers and the databases built during this work are gathered in a geographical database called "*Base de Données Géographique de la VÉGétation de la France*" (BDGveg_FR). The main covers show respectively the vegetation succession stages, as a georeferenced scan, at 1/200,000, and the harmonised map of the potential vegetation, in a vector format, at 1/1,000,000. The harmonised map of the potential vegetation is linked with a national 6-level typology synthesised from the keys of the 64 sheets. The BDGveg_FR is unique because of its period of time, its local and national scales, its exhaustive cover, and its information on the plant associations. Thus, it is actually complementary to the other databases on the French vegetation presently available. It is particularly well appropriate to assess the impact of global changes (*e.g.* climate, atmospheric pollution) on ecosystem behaviour.

Introduction
Between 1947 and 1990, the "*Centre National de la Recherche Scientifique*" (CNRS) published 64 paper sheets which form a vegetation map of the metropolitan French territory. This vegetation map draws two kinds of information: the succession stages at the date of the survey and the natural potential vegetation, *i.e.* the vegetation that should develop considering the partly irreversible environmental changes (see Ozenda, 1986; Härdtle, 1995). This paper map is a unique source of information for the French territory with its detailed scale, the period of time it concerns, its exhaustive cover, and the vegetation data it provides (Rey, 2009). In this note we present the digitalisation

of the vegetation map of the CNRS, the geographical covers, and the databases produced. A detailed description of the mapping process, the maps produced as well as several applications is available in Leguédois *et al*. (2011).

Mapping sources

Each sheet of the vegetation map of the CNRS includes:

- the map *sensu stricto* at 1/200,000 which gives the succession stages at the time of the survey;
- a series of seven insets at 1/1,250,000 characterising the agricultural and ecological conditions of the mapped territory and, among them, the botanical inset which represents the natural potential vegetation;
- a detailed key specific to the sheet.

The global coherence of the vegetation map of the CNRS has been ensured (Gauquelin *et al.*, 2005) by: (i) a relatively short surveying period (80 % of the 64 sheets were edited between 1963 et 1985), (ii) the small number of main authors (19 authors are responsible for 94 % of the sheets), (iii) the centralised management (the "*Service de la Carte de Végétation*" created in 1945 in Toulouse) and, (iv) a common mapping method even though the mapping rationales have been adapted with the authors and the periods. The cornerstone of this classification is the succession which actually reflects the different stages leading to the climax vegetation. However some mapped vegetation series represent only one single stage of the succession like pine forests or some oak forests in lowland. Moreover, depending on the authors, the mapped natural potential vegetation can reflect either the site natural conditions only, or the site natural conditions plus the durable man-made changes (*i.e.* pollution, soil erosion, drainage, species naturalisation like Maritime Pine in the Landes). Despite these mapping inconsistencies inherent to each classification system, the data provided by the vegetation map of the CNRS is a unique, reliable, detailed, rare , and exhaustive source of information for the considered period.

Digitalisation and harmonisation

A set of digitalisation and harmonisation procedures have been followed to produce the different items constituting the BDGveg_FR.

The map *sensu stricto* as well as the insets (except the relief inset) of the 64 sheets have been scanned at high resolution (600 dpi) and then patched as well as georeferenced to produce seven continuous raster covers for the whole metropolitan French territory. The georeferenced scan at 1/200,000 issued from the map *sensu stricto*, is the succession stage cover which reproduces the original paper map. The six others georeferenced scans are secondary covers which represent the 1/1,250,000 insets of the paper map: botanical data, soil conditions, soil use, agriculture, climate, and agricultural restrictions.

The harmonised vector cover of the natural potential vegetation at 1/1,000,000 is based on the 1/1,250,000 botanical insets of each of the 64 sheets of the paper map of the CNRS. Because of the inconsistencies of classification between the different sheets (see previous section) a harmonisation work was needed. This harmonisation has been done in two steps: firstly the synthesis of a national typology based on the legends of the 64 maps at 1/200,000 and, secondly, the digitalisation of the botanical insets. The general idea of the synthesis of the typology was to homogenise, as efficiently as possible at a national level, the information of the 64 sheets while trying to stay closer to the original legends. It resulted in a national nested 6-level typology of the vegetation of France. The digitalisation of the natural potential vegetation cover results from the vectorisation, the patching, and the georeferencing of the 64 botanical insets. The precision of the georeferencing (from 100 to 800 m depending on the considered region) agrees with a use at 1/1,000,000. Each polygon of the natural potential vegetation cover has been assigned to one type of vegetation as classified in the 5th level of the typology. The chosen type of vegetation and the mapping limits have been checked against the original paper maps of the CNRS and others vegetation maps at the local scale (more particularly Ozenda et Wagner, 1975; Ozenda et Lucas, 1987).

Results and discussion

All the digital information produced during this work has been gathered in a geographical database, called "*Base de Données de la VÉGétation de la France*" (BDGveg_FR). The BDGveg_FR contains:

- a 1/200,000 georeferenced scan of the succession stages which is a testimony of the vegetation of the years 1940–1990;
- a harmonised 1/1,000,000 vector cover of the potential vegetation (Fig. 1) with descriptive data for each mapping unit; this cover has been checked and verified by comparison with other maps (see previous section) and the floristic heterogeneity of each mapping unit has been quantified;
- a database of the 6-level typology (Fig. 2) of the French vegetation which can be joined to the harmonised potential vegetation cover at the 5th level (Vegetation Mapping Units or VMU);
- six secondary covers as georeferenced scans which correspond to the insets of the paper map (soil, land cover, agriculture, climate, local potential vegetation) as well as 10 vector covers which regroup data extracted

from the botanical inset (main secondary tree species, distribution area of some Mediterranean species, and drainage level);

- a database with the main metadata for each paper sheet (authors, collaborators, publication date, number, name, extent).

The vegetation information of the BDGveg_FR is more synthetic than the distribution data of species gathered in floristic geographical databases (Brisse *et al*., 1995; Drapier et Cluzeau, 2001; Gégout *et al*., 2005).

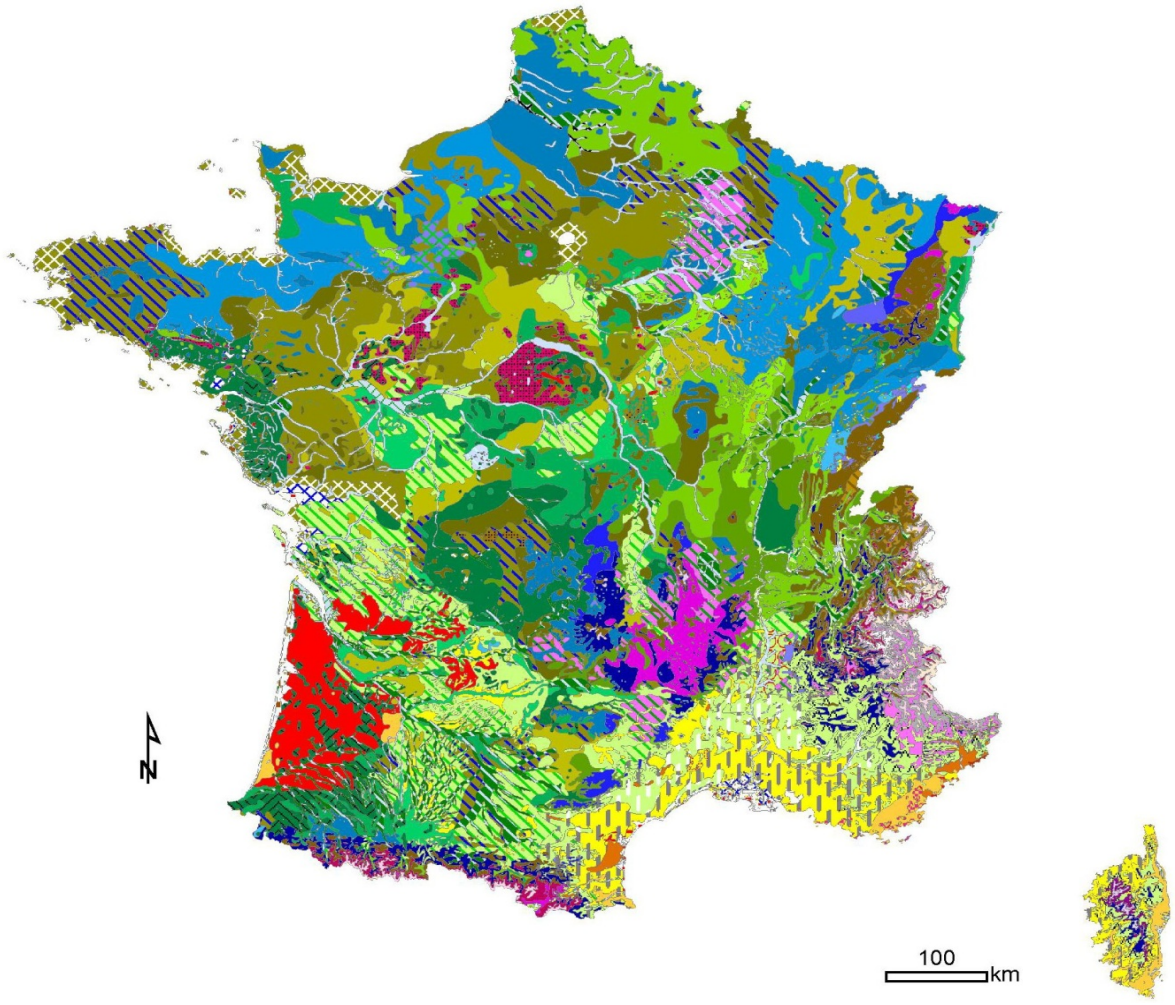

Fig. 1: Harmonised map of the French natural potential vegetation (Leguédois *et al.,* 2011). The detailed legend is shown in Fig. 2.

Conclusion and perspectives

The BDGveg_FR is a novel geographical database on the French vegetation which fills a gap in the available databases by the period of time its covers (1940–1990), its local and national scales (1/200,000 and 1/1,000,000), its exhaustive cover, and the information it provides on the plant associations. The BDGveg_FR could be used to analyse long-term and large-scale impacts of global changes like climate, atmospheric pollution or tree species substitution as well to design sampling schemes. An equivalence between the EUNIS European classification and the VMUs has already been established. It enables assessment of the impacts of long range atmospheric pollution at the European level (Probst *et al*., 2012). On an applied point of view, this database could be used to characterise the biogeographical and ecological situation of naturalist studies or environmental impact assessments as well as to help vegetation mapping by remote sensing. For example, current stages of vegetation could be obtained by combining the harmonised map of potential vegetation with the Corine Land Cover database[1]. It is also an attractive teaching material.

1 *http://www.statistiques.developpement-durable.gouv.fr/donnees-ligne/li/1825/1097/occupation-sols-corine-land-cover.html* [In French, checked 07/07/2014].

1. Planar belt

111. Marine and coastal areas
1111. Marine vegetation
11111: Marine vegetation
1112. Coastal grasslands
11121: Coastal marshes and salt meadows
11122: Coastal heathlands and grasslands
1113. Coastal vegetation on mineral soils
11131: Cliffs, sands and pebbles
11132: Dunes
1114. Coastal scrublands
11141: Groves and scrubs
112. Non-forested inland wetlands
1121. Non-forested inland wetlands
11211: Halophytic vegetation
11212: Aquatic and helophytic vegetation, dry grasslands on alluvial sands
11213: Oligotrophic and acidic bogs
11214: Eutrophic and alkaline fens
113. Riparian woodlands
1131. Black alder forest
11311: Bog-alder forest
11312: Black alder forest
1132. Grey alder forest
11321: Grey alder forest
1133. Alder-willow-poplar forest
11331: Alder-willow / alder-poplar forest
1134. Alder-ash-elm forest
11341: Alder forest with ash or elm
1135. Alder-birch forest
11351: Alder forest with birch
1136. White willow forest
11361: White willow forest
1138. Riparian pedunculate oak forest
11381: Riparian pedunculate oak forest on calcareous substrate

2. Colline belt

21. Lower to middle colline belt
211. Pedunculate oak-dominated woodlands
2111. Acid pedunculate oak forest
21111: Pedunculate oak forest and acid heathlands
2112. Neutrocalcicolous to eutrophic pedunculate oak forest
21121: Mesotrophic to eutrophic pedunculate oak forest
21122: Calcicolous pedunculate oak forest
2113. Mixed forest with pedunculate oak (and hoary oak)
21131: Acid pedunculate oak forest with hoary oak
212. Sessile oak-dominated woodlands
2121. Acid sessile oak forest
21211: Acid sessile oak forest
2122. Meso-neutrophile to calcicolous sessile oak forest
21221: Sessile oak forest and meso-neutrophile heathlands
21222: Calcicolous sessile oak forest
213. Mixed-oak woodlands
2131. Acid mixed-oak forest
21311: Mixed forest with sessile and pedunculate oaks, hornbeam and beech, acid heathlands
2132. Calcicolous mixed forest
21321: Calcicolous mixed forest with sessile and pedunculate oaks
2133. Meso-neutrophile mixed-oak forest
21331: Meso- to eutrophic mixed forest with sessile and pedunculate oaks, scrublands and grasslands
21332: Sessile and pedunculate oaks, hornbeam and beech
21333: Bocage of pedunculate oak, elm, hornbeam and beech, with meadows and grasslands

22. Middle to higher (and submontane) **belt**
221. Beech-oak woodlands
2211. Acid beech-oak forest
22111: Acidiphilous beech-sessile oak forest, scrublands and grasslands
2212. Meso-neutrophile beech-oak forest
22121: Neutrophile beech-sessile oak forest, scrublands and grasslands
2213. Calcicolous beech-oak forest
22131: Calcicolous beech-sessile oak forest, scrublands and grasslands
222. Pubescent oak woodlands
2221. Pubescent oak forest
22211: Pubescent oak forest
22213: Mixed pubescent oak forest with various broad-leaved trees, scrublands and grasslands
2222. Patched evergreen oak forest
22221: Evergreen oak forest
223. Scots pine woodlands (and pubescent oak)
2231. Scots pine forest
22311: Scots pine
22312: Scots pine and oaks (mainly pedunculate)
2232. Planted conifers
22321: Planted spruce, Douglas-fir, fir and larch
22322: Planted Scots, maritime, black and Mediterranean pines

23. Thermo- and middle Mediterranean belt
231. Pubescent oak woodlands
2311. Pubescent oak forest
23111: Pubescent oak forest, associated scrublands and grasslands
23112: Pubescent oak forest, mulberry type, associated scrublands and grasslands
23113: Pubescent oak forest, hop hornbeam type, associated scrublands and grasslands
2312. Mixed-oak forest with pubescent and evergreen oaks
23114: Mixed-oak forest with pubescent and evergreen oaks
23115: Mixed-oak forest with pubescent and evergreen oaks, mulberry type
232. Evergreen oak woodlands
2321. Evergreen oak forest
23211: Evergreen oak forest and xeric calcicolous garrigue
23212: Evergreen oak forest and xeric calcicolous garrigue, Phoenician juniper type
23213: Evergreen oak forest and xeric calcicolous garrigue, lentisk pistache type
23214: Evergreen oak forest and xeric calcicolous garrigue, myrtle type
23215: Evergreen oak forest and xeric calcicolous garrigue, olive-lentisk type
233. Cork-oak woodlands
2331. Cork-oak forest
23311: Well-drained cork-oak forest
23312: Well-drained cork-oak forest, oleander type
23313: Well-drained cork-oak forest, myrtle type
23314: Well-drained cork-oak forest, olive-lentisk type
234. Mediterranean pines woodlands
2341. Mediterranean pines forest (Aleppo, Salzmann's, umbrella)
23411: Calcareous Mediterranean pines forest (Aleppo, Salzmann's, umbrella)
23412: Calcareous Mediterranean pines forest (Aleppo, Salzmann's, umbrella), carob tree type
235. Maritime pine woodlands
2351. Maritime pine forest
23511: Siliceous pine forest

3. Montane belt

31. Submontane belt
311. Beech woodlands
3111. Acid beech forest
31111: Acid beech forest
3112. Calcicolous and neutrophile beech forest
31121: Meso-neutrophile to acidocline beech forest
31123: Calcicolous beech forests
31124: Cold calcicolous beech forest
31125: Thermo-calcicolous beech forest
3113. Lime-maple forest
31131: Hygrosciaphile beech forest with lime and maple (fir in the western regions)

32. Low to middle montane belt
321. Fir and beech-fir woodlands
3211. Beech-fir and fir forest
32111: Beech-fir and fir forest
322. High altitude beech woodlands
3221. High altitude beech forest
32211: High altitude beech forest, heathlands and grasslands
323. Scots pine woodlands
3231. Scots pine forest
32311: Acid Scots pine forest
32313: Calcicline Scots pine forest

33. High and oro-Mediterranean belt
331. Pubescent oak woodlands
3311. Pubescent oak forest
33111: Pubescent oak forest, scrublands and grasslands
332. Evergreen oak woodlands
3321. Evergreen oak forest
33211 Maquis of the evergreen oak forest from Corsica
333. Oro-Mediterranean pine woodlands
3331. Open forest with Corsican pine
33311: Open woodland with Corsican pine

4. Subalpine (and high-Mediterranean, from Corsica) belt

411. Spruce woodlands (humid variant)
4111. Spruce and fir-spruce forest
41111: Spruce forest with beech and fir (including peatlands), heathlands and grasslands
4112. Mesophilous spruce forest
41121: Spruce forest (including peatlands), heathlands and grasslands
412. Spruce woodlands (dry variant)
4121. Meso-xerophile spruce forest
41211: Dry spruce forest, heathlands and grasslands
413. Spruce and fir woodlands
4131. Fir and spruce forest
41311: Fir forest with spruce (including peatlands), heathlands and grasslands
414. Subalpine pine woodlands
4141. Pine forest with mountain and Swiss stone pines
41411: Mountain pine forest (including peatlands)
415. Larch woodlands
4151. Larch forest
41511: Open larch woodland
416. Subalpine heathlands and grasslands
4161. Rhododendron-juniper heathlands
41611: Heathlands and grasslands, scrublands

5. Alpine belt

511. Alpine (or pseudo-alpine) heathlands and grasslands
5111. Calcicolous heathlands and grasslands
51111: Alpine grasslands on limestone
5112. Siliceous heathlands and grasslands
51121: Alpine siliceous grasslands
512. Nival belt
5121. Rocks, snow and ice
51211: Rocks, snow and ice (lichens and algae)

Non mapped

Fig. 2: Detailed legend of the harmonised map of potential vegetation of France (Leguédois *et al.*, 2011). Only VMUs depicted on the map (Fig. 1) are presented here.

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